IMPACT OF CLIMATE CHANGE OF BRAHMAPUTRA RIVER BASIN ON URBAN DRAINAGE OF GORANCHATBARI, DHAKA

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Abstract An urban inundation model, combining a storm sewer model SWMM and operations of Goranchatbari pumping station, has been developed to simulate inundation in urban areas due to storm water and outlet pumping station. The movement of water in the studied Goranchatbari watershed is characterized by two components, namely, the storm water flow component and the inundation component. SWMM is employed to solve the storm water flow component and to provide the flow hydrographs for surface runoff exceeding the capacity of the storm water. Drainage by pumping stations at outlets of the storm water system has also been taken into consideration. The parameters of the Goranchatbari model are calibrated and verified for discrete storms. SWAT simulation with extreme scenarios RCP 8.5 over the Brahmaputra basin provided the discharge data of Bahadurabad station. Flood frequency analysis using 20yr, 50yr, and 100yr flood will be conducted for Bahduarabad station and will correlate with Turag River station. The effect of outfall water level due to climate change will be incorporated in this SWMM drainage model to generate future scenarios of study area. The combined study is suitable for analysis of inundation on urban areas due to overflow of storm water and flooding caused by Climate Change. Simulated results can be applied to establish flood-mitigation measures.

1. Introduction

Rainfall induced flooding during rainy season is a regular phenomenon in Dhaka City (A.K. Gain et al. 2012). Almost every year a significant part of the city suffers badly with drainage congestion. There are some highly dense areas with lower ground elevation which submerge under water even with an intense precipitation of few hours. The higher areas also suffer with the drainage problem due to inadequate maintenance of the system and encroachment or illegal filling up of the drainage canals and lakes (Sarder et al. 2010). Most part of the city suffered from long term urban flooding during historical extreme rainfall events in September 2004, 2007 and July 2009. The situation is likely to worsen in the future due to Climate Change, which may lead to more frequent and intense precipitation (Sonia Binte Murshed et al. 2011). Therefore, it is an obvious need to investigate the future impacts and possible remedial measures so that proper steps can be taken at the earliest to reduce the potential damages in future caused by urban flooding (Sujit Kumar Bala et al. 2009). Storm-water modeling has a major role in preventing issues such as flash floods and urban water-quality problems. Storm-water models of a lowered spatial resolution would thus appear valuable if only their ability to provide realistic results could be proved (M. R. Kabir et al. 2006).

This study proposes a methodology for rapid catchment delineation and storm-water management model (SWMM) parameterization in a large urban area with model calibration and validation (SWMM 2010). There are some efficient commercial tools available e.g. MIKE Urban, Sobek Urban, MIKE 11 etc. to develop drainage models but for the sake of collective research potential, open source modelling tool is considered. Out of many open source tools EPA's Storm Water Management Model (SWMM) and Bentley's Storm CAD are widely used over the world (Timothy O. Erickson et al. 2010). The drainage system of Dhaka is consisting of both open channel and storm sewers. Storm CAD can only represent a piped system but SWMM has the capability to represent both open channels and pipes (T. Arriero et al. 2013). Based on the above mentioned facts Storm Water Management Model can be recognized as a prime open source tool for simulating the drainage system of study area (Sadia Afrin et al. 2015).

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The "Study on Storm-water Drainage System Improvement Project in Dhaka City" was one of the first major studies focusing on the drainage problems of the city. After the 1988 flood, the study was reviewed and updated in 1990. The aim of both studies was to prepare a phased drainage improvement program and identify priority projects with preliminary designs. The 1988 floods also prompted the Government to formulate a 26-component Flood Action Plan (FAP), which was coordinated by the World Bank. One of these components was FAP 8A (Greater Dhaka Protection Project - Study in Dhaka Metropolitan Area) (IWM 2006, IWM 2011). The 'Dhaka City Integrated Flood Protection Project' (FAP 8B) was conducted by Louis Berger International (1991) and financed by the ADB.DWASA engaged IWM to undertake the "Study on Drainage Master Plan for Dhaka City" (ADB 2013). The aim of the study was to evaluate previous drainage studies in light of changed city situation and provide recommendations to improve the drainage system. The Detailed Area Plan (DAP) was undertaken by RAJUK in order to implement the structure plan and urban area plans of the 1995 Dhaka Metropolitan Development Plan (RAJUK 2010). One of the purposes of DAP was to improve drainage system of the area and protect flood flow from encroachment. IWFM (2005) undertook a study of the 2004 flood which heavily affected the Greater Dhaka area (IWFM 2005). The study focused on identifying the main features of the flooding in terms of extent (area) affected, timing and duration of inundation, etc.

The intensity, duration, and geographic extent of floods in Bangladesh mostly depend on the combined influences of three river systems, Ganges, Brahmaputra and Meghna (GBM). In addition, climate change is likely to have significant effects on the hydrology and water resources of the GBM basins and might ultimately lead to more serious floods in Bangladesh (M. Masood et al. 2014).The calibrated model has been used to assess the impact of climate change on water availability of BRB by applying different climate change scenarios of selected General Circulation Models (GCM). The selection of GCM was based on the Representative Concentration Pathways (RCPs) scenarios of eight Intergovernmental Panel on Climate Change (IPCC) GCMs for the 21st century (Sarfaraz Alam 2015). In order to efficiently and effectively apply the SWAT model, different calibration and uncertainty analysis methods have been developed and applied to improve the prediction reliability and quantify prediction uncertainty of SWAT simulations. (Xuesong Zhang et al. 2009). So a semi-distributed hydrological model of the Brahmaputra River Basin (BRB) has been setup using Soil Water Assessment tool (SWAT). It has been calibrated and validated for the streamflow measured at the Bahadurabad station for the periods of l98l to 2010 and satisfactory goodness-of-f statistics were found (Alam et al. 2015). During the late 1980s and early 1990s, awareness of the shortage of global water resources lead to the first detailed global water resources assessments comparing water availability with water use. (Marc F. P. Bierkens, 2015).

A relatively complex scenario with simultaneous uncertain inflows into a flooded domain, a satellite-based forecast of the flood with high accuracy is possible through the assimilation of the satellite-based Model into a flood forecast model. (Javier García-Pintado et al. 2015). In Bangladesh, the economic value of freshwater makes this resource one of the highest-priority issues with respect to the impact of and adaptation to climate change. According to the fifth Assessment Report of the (IPCC, 2014), an intensification of the hydrological cycle in a future warmer climate is expected for this country. Bangladesh is the largest delta in the world. Himalayas produces huge sediment as the young mountain (Fabrice Papa et al. 2012). The Ganges and the Jamuna are draining the southern and northern slopes of the Himalayas which are carrying more than one billion tons of sediment every year (Aquastat 2011). The huge sediment has built up the world's largest delta and made the river and estuary very dynamic and quickly responding (Fabrice Papa 2010). In Bangladesh, the potential impacts of climate change are of great importance because of global warming (Jogendra Nath Sarma et al. 2015). As a result of climate change, river flooding may increase in duration and flash flooding will tend to be more frequent as cyclones. Surge depths will increase, and a sea level rise of 0.5m by 2050 would exacerbate drainage congestion (IWM and CCC 2008). In the coastal area of Bangladesh the probable impacts of climate change/ sea level rise are more coastal erosion, sedimentation in the estuary will further aggravate drainage congestion, flooding, navigability and cyclones with higher frequencies and intensities. The morphological changes would have severe implications on agriculture, food security, socio-economic development and general livelihood of the coastal communities (Goswami D.C et al. 2003).

A number of studies were carried out in the 1990's under the Flood Action Plan (FAP). In total 25 studies were carried out. The studies provided new bathymetry, hydraulic and sediment data within the rivers of Bangladesh, as well as analysis of sediment transport and morphology (Ramesh Ananda et al. 2014). Basically all main rivers and many secondary Rivers of Bangladesh are covered in the FAP studies. For the main rivers, the primary focus was on Ganges, Jamuna, Padma and Lower Meghna. Hence, only little work was made on the rivers surrounding Dhaka. The specialist reports of FAP24 and FAP6 are useful for the present study

(IWM 2006, IWM 2011). The base line information study by JICA (JICA, 2000) is the only account which describes the morphological changes in the rivers surrounding Dhaka. IWM also reports on cross section data and change of water-levels of the rivers. As part of the JICA 2000 study, additional cross section surveys were carried out, and historical satellite images retrieved and analyzed. With this information the study determined the changes in top width and bank line changes of the river system.

2. Objectives

The impact of climate change will be felt across the country. But the nature of impact will be different in urban and rural areas. The former will face greater threat of inundation due to over-topping and possible breach of flood protection embankments, which may become further exacerbated due to internal drainage congestion. Whereas both are socially and economically important, this paper will deal with the former, with specific focus on western part of Dhaka – the capital city of Bangladesh.The specific objectives of this paper are:

- Assess the impact of global climate change on Bangladesh in terms of major parameters that include discharge and water level using SWAT Model run data.
- Relate the projected changes in these parameters to the stream flows and water levels of the Turag River near to Mirpur of Dhaka City.
- Analyze the potential impacts on the flood situation in Western Dhaka in the years 2030, 2050 and 2099 based on the present status of flood management.
- Suggest adaptation and mitigation measures.

3. Model Developments

3.1. Goranchatbari SWMM development

The first step to set-up a SWMM model will be the catchment delineation which is divided the total study area into small sub catchments according to the understanding of the drainage system and flow direction of storm-water (Henri Tikkanen 2013). The existing study area stream network is burn into the Dhaka digital elevation model (DEM) with ArcGIS 10.1 which is a powerful tool for catchment delineation (K. H. V. Durga et al 2014). The rain gauge station of Bangladesh Meteorological Department (BMD) is used in this model. The sub catchment boundary will be imported from GIS Shape file (James 2009). The parameter sub catchment width is calculated from drainage network, sub catchment boundary and area (N. Hoegh Nielsen et al. 2011). Percent of impervious and pervious area is calculated from existing and future land use pattern and applied in sub catchment property (David J. et al 2015). For other parameter standard values will be used (Fred L. et al. 2011). All available data, maps and reports, such as road network master plan, drainage master plan, land-use map, and structure plan of the city, utility maps were collected from respective offices. A critical review of the previous drainage studies and drainage basin maps of Goranchatbari was conducted and assess their adequacy in addressing current drainage problems. Study the trend in hydro-meteorological changes and identify impacts on the drainage systems in the future.

Drainage Improvement study: Asses the major and minor drainage systems and elements of the urban basins using the hydrodynamic modelling and, through this, identifying the flooding events and areas, taking into account the current situation and future flood or drainage scenarios (F. A. Beling et al. 2011). Develop structural and non-structural interventions designed to eliminate the flooding events and areas for pre-determined design horizons and flood intensities, and verify the effectiveness of the proposed interventions for the current and future flood or drainage scenarios using the hydrodynamic model (N. Hoegh Nielsen et al. 2011). Using the hydrodynamic model, simulate the occurrence of the flood risk events with and without the proposed structural and non-structural interventions, developing flood risk maps which will assist in decision–making regarding flood prevention and emergency responses (A. Pathirana et al. 2011). Determine the criteria to be used for designing and constructing of drainage structures, such as storm drains, channels, retention storages and pumping stations (Floris Cornelis Boogaard 2015). Criteria include design rainfall, minimum and maximum velocities, minimum and maximum channel slopes, side slopes, depths, etc. (Floris 2015).

Complete hydrodynamic modelling for Goranchatbari of the drainage system and produce GIS based inundation maps. Maps must depict scenario based on current and future conditions in 2040 with and without the recommended drainage improvement. Study the sediment transport capacity and geomorphic characteristics of drainage system (William Solecki et al. 2011). Review the Dhaka Metropolitan Development Plan (DMDP) and regional urban development plans to assess the integration of drainage issues of Goranchatbari with rest of the infrastructure issues. Considering drainage basin, Dhaka city is being divided into western and parts. Western Dhaka is protected from river flooding by the embankment constructed along Turag and Buriganga rivers under FAP8 program.

The drainage network comprises open channels, covered drains and pipe network. Dhaka WASA maintains a 65.46 km long storm conduit line which mainly carries the drainage from different parts of Goranchatbari system to Turag River. The alignments and invert levels have been collected. In the core city area, there exists about 3 natural khals totalling a length of 145 km. These natural canals are the main arteries of the existing drainage systems for DWASA. They have been collected for this study river geometry required as model inputs has also been collected from BWDB and BIWTA. Spot levels of surface elevations have been collected from RAJUK, supplemented by topographic maps from SoB. This collected data were used to update the DEM of Goranchatbari which will be used as baseline condition for topography and for generating inundation maps at the next stage. BWDB is maintaining one at Goranchatbari to pump out stormwater into the receiving waters beyond the embankment. Frequency analysis was performed to determine 100 year high flood level of surrounding area of Dhaka city. Mirpur Station (SW-302) which is near kallyanpur pump station covers the Ashulia, Aminbazar and surrounding area. Table 1 provides the summary of High Flood Level at Mirpur (SW302) station for different year return period.

Table 1. Frequency analysis of Turag River water level on Mirpur

Mirpur WL (SW302)					
2 Yr	**5 Yr**	**10 Yr**	**20 yr**	**50 Yr**	**100 Yr**
5.9	6.5	6.9	7.3	7.8	8.2

Pumping Level: To identify the pumping level and duration water level data has been analyzed for different stations. Kallyanpur pump is close to Mirpur gauge station (SW302) and the pumping level starts from 3.80 mPWD. The Goranchotbari pump station is 3.5 km north of Kallyanpur pump and the starting level is 3.50 mPWD. The western and southern part of Study area is almost developed and consists of complex pipe networks and khals. Furthermore this part is under mainly pump drainage during the monsoon season. The EPA-SWMM model has been developed for this part of the city which comprises all the major pipes, Box culverts, khals, storage areas and pump stations (Moynihan et al. 2014). The model setup includes preparation of hydrology, hydraulics time series data and different types of curves. The model was simulated after developing all the components of hydrology and hydraulics.

The potential scenarios were developed based on the intensity duration frequency curve designed for the study area. 30min, 1hr, 2hr, 3hr, 6hr, 24hr, 36hr, 48hr and 72hr design rainfall for 2yr return period were selected for analysis for this stage of the study. All these design rainfall were converted to time series data with suitable interval to make it compatible for simulation through which a rainfall runoff hydrograph was produced for each catchment. A detailed modelling approach has been carried out under this study is to establish design flow in each of the catchment and each of the river/ khal/ pipe in the model domain (Shouhong Zhang et al. 2014). A number of potential options were devised based on the duration of rainfall and for different return period. The durations of rainfall are 30min, 1hr, 2hr, 3hr, 6hr, 24hr, 36hr, 48hr and 72hr and the return periods are 2yr. It is evident from the simulated results that the most vulnerable event is 24hr duration rainfall as it gives maximum runoff in each of the catchment for 2yr return periods. That is why 24hr duration rainfall can be selected for all the planning and design for core city and its surrounding area. The Hydrological model SWMM was simulated for different duration of 2 year return period.

Table 2. Changes of Peak Flow of Goranchatbari catchment area.

Sub-CA	Peak Flow (m^3/s)					
	0.5-hr	**1-hr**	**2-hr**	**3-hr**	**6-hr**	**24-hr**
GCB	149.55	245.19	258.55	269.99	133.05	146.96

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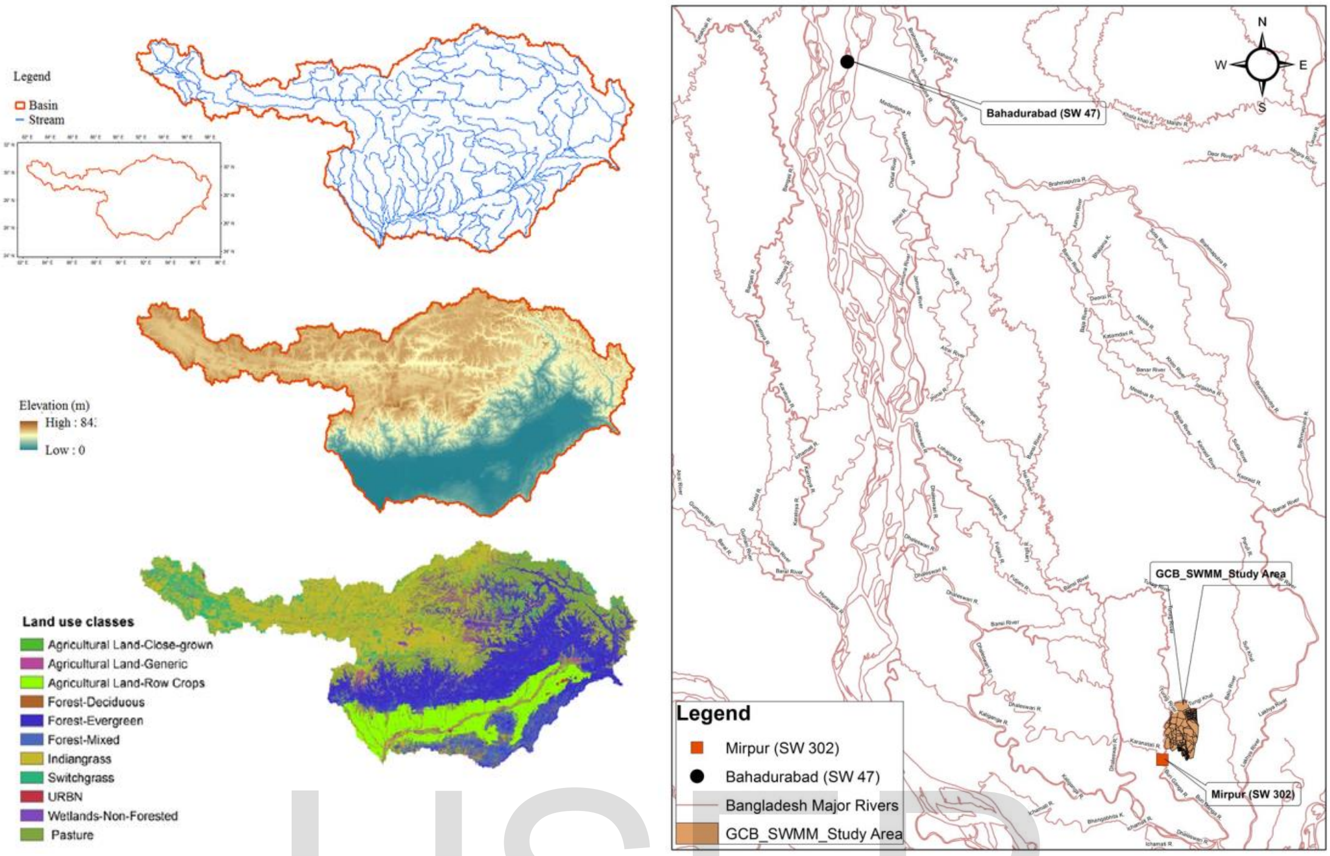

Fig 01: Brahmaputra BASIN SWAT Model Set-up and connection with study area

The peak runoff of all the sub catchments under all basins in SWMM is described on Table 3. It shows that 1 hour and 3 hour rainfall produces critical runoff for different basins in the core city. The Baunia khal which carry major part of runoff was encroached in many places and narrowed. At one location capacity of the khal is reduced which slows down the flow. Existing low land at the upstream of Baunia khal works as temporary reservoir. The existing storage capacity of Goranchotbari pump station is about 247 ha which is satisfactory for 2 year design rainfall. The existing pumping capacity of Goranchotbari pump station is 22 m^3/s. BWDB is increasing the capacity up to 44 m^3/s which is sufficient for 2 year design rainfall.

3.2. SWAT Model setup

Several types of data are required as input for SWAT to develop model using the ArcSWAT interface (Z. M. Easton 2010). Topographic data have been obtained from the Shuttle Radar Topographic Mission (SRTM) with a spatial resolution of 90 m. The sub-basin parameters, such as slope gradient, slope length of the terrain and the stream network characteristics (channel slope, length and width) have been derived from the analysis of Digital Terrain Model. The DEM has been masked for the Brahmaputra basin area as shown Fig.01. Land-use maps are required for the delineation of the HRU of the model. A 300 m resolution land-use from 2009 to 2010 are collected from Europe Space Agency GLOBCOVER. This data has been reclassified to match the SWAT Land classes. Soil map of the study area was collected and extracted from the FAO digital soil map of the world (Pipas 2015). Watersheds have been delineated through automatic watershed delineation techniques (Ficklin et al. 2012). A threshold for minimum sub-basin area has been selected for the stream network and outlet calculation.

3.3. *Observed Discharge data:*

River discharge data have been collected from Bangladesh Water Development Board (BWDB) for Bahadurabad station (Station No. SW 46.9) on the Brahmaputra River. The location of the Bahadurabad station has been shown in Fig. 02. Flow data of this station are used for model calibration and validation.

BWDB does not measure discharge data on a daily basis. Rating curve has been used for determining daily discharge from daily water level data. The quality of the stage-discharge relation or rating curve determines the quality of computed stream flow data. Hydraulic theory helps in determining the general form of the rating curve. As Bahadurabad station on the downstream of the Brahmaputra basin have been selected as the watershed outlet, this delineation resulted in a watershed of area of 510452.91 km^2 and a total of 39 sub-basins. In order to assess these impacts, computer simulation modeling was carried out for three projection years 2030, 2050 and 2099.

3.4. Climate Data: SWAT requires daily or sub-daily observed meteorological data such as rainfall, maximum and minimum temperature, relative humidity, solar radiation and wind speed, etc. (K.C. Abbaspour et al. 2015). Climate data has been obtained from TRMM (Tropical Rainfall Measuring Mission) and ERA-Interim. The land-use and soil maps, as derived from above mentioned methods, have been imported and linked with the respective database table to create appropriate lookup tables. 'Multiple HRU' option has been selected which generates 304 HRUs for the whole watershed. For TRMM datasets, a period of 5 years (2000 - 2004) has been selected for calibration and 5 years (2005 - 2009) for validation. In addition, 1 year has been kept as warm-up period for both calibration and validation. A warm-up period allows the model to get a fully operational hydrological cycle and thus helps to stabilize the model. The main methods used in modeling the hydrologic processes in SWAT were curve number method for runoff estimating (S. Paul et al. 2014), Penman-Monteith method for PET and Muskingum method for channel routing (Z. M. Easton et al. 2010).

Table 3: 11 different RCMs under RCP scenario 8.5.

Model Data Source	Denoted on this study	Model Data Source	Denoted on this study
Access1-0_csiro-ccam-1391m	M1	Miroc-miroc5_smhi-rca4	M7
Ccsm4_csiro-ccam-1391m	M2	Mpi-esm-lr_csiro-ccam-1391m	M8
Cnrm-cerfacs-cnrm-cm5_smhi-rca4	M3	Mpi-m-mpi-esm-lr_mpi-csc-remo2009	M9
Cnrm-cm5_csiro-ccam-1391m	M4	Mpi-m-mpi-esm-lr_smhi-rca4	M10
Ichec-ec-earth_smhi-rca4	M5	Noaa-gfdl-gfdl-esm2m_smhi-rca4	M11
Ipsl-cm5a-mr_smhi-rca4	M6		

Climate scenarios from 11 different RCMs under RCP scenario 8.5 have been used to derive the SWAT model. Model has been simulated for the historical period from 1980 to 2009 which is considered as baseline or historical simulations (Md Shahriar et al. 2014). Future river discharge for the Brahmaputra River has been estimated for three time windows, 2020s (2010-2039), 2050s (2040-2069) and 2080s (2070-2099).The above data were fed into the SWAT model of Brahmaputra Basin and the discharge data for Bahaduarabad Station was generated by performing simulation on the model. The RCMs were fed in the model on the **Table 3**.

Data origin: The raw RCM output was retrieved from the repositories of Earth System Grid Federation (ESGF), the Indian Institute of Technology Madras (IITM) and from Swedish Meteorological and Hydrological Institute (SMHI). The reference dataset used for the bias correction is the hybrid dataset of Watch Forcing Data - WFD (Weedon et al 2010) and the Watch Forcing Data methodology applied to ERA-Interim data (WFDEI) (Weedon et al 2014) used in the Inter-Sectoral Impact Model Integration and comparison Project ISI-MIP which combines forcing data of WFD (1901-1978) and WFDEI.GPCC (1979-2012) (Lila et al 2013). The bias correction methodology applied to the precipitation data is the one described (Claudia et al. 2012). For the rest of the climate variables, the same methodological principles are applied on different type of transfer functions due to differences in the data nature (Leilei 2013). As bias correction reference period, the 1981 – 2010 was considered. The 0.5° regular grid of WFD was used as reference. All the climate data were interpolated to this grid before the bias correction (Matthias et al. 2011).

3.5. *Projected Sea Level Rise:* The southern part of Bangladesh being very active and morphology dynamic delta, it is difficult to develop a specific scenario for the net change in sea level along the coastal areas (RITES 2010). Considering a combination of relative subsidence of the delta and rise in sea level will give an indication of net change in sea level (Rahman M.M. 2011). According to World Bank, the overall change in sea level by the year 2030 will be 30 cm and by the year 2050 it will be 50cm (Lucia et al. 2010). The

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interesting aspect of net sea level change is that higher ocean stage along the river mouth will tend to generate a strong backwater effect, leading to further deceleration of draining water from the rivers. Such a possibility would have a compounding effect on flood vulnerability (Muhammad et al. 2015). Since the confluences of the GBM system is within 50~70 Km from the Bay of Bengal, it is likely that the presence of a strong backwater effect will impede recession of flood waters, thereby increasing duration of floods (N. Forsythe et al. 2014).

3.6. *Impact of Flood Hydrograph:* S. Kay et al. 2015 have studied impacts of climate change on peak discharge of various rivers. The changes in peak discharge for the three largest rivers in Bangladesh have been used as shown in **Table 4**. It may be noted that the changes in peak discharge are relatively higher between 2050 and 2030, than between 2030 and 1990.

Table 4. Changes of peak discharge of three major rivers in Bangladesh from 1990 to 2099.

River	Change in Peak Discharge (m3/s)	
	1990-2030	2030-2050
Ganges	2745	3708
Brahmaputra	377	509
Meghna	793	1071

4. Results and Discussions

The projected rating curves have been drawn at Bahadurabad river (SW 46.7) incorporating the expected peak discharge and the projected runoffs to predict the future water levels of this station. The projected rating curves of Bahadurabad observed stations on Jamuna Rivers for different years show that the change of water levels. According to rating curves, the SWAT Model discharge data were changed to water level of this observed station and predicting the future water level for this station.

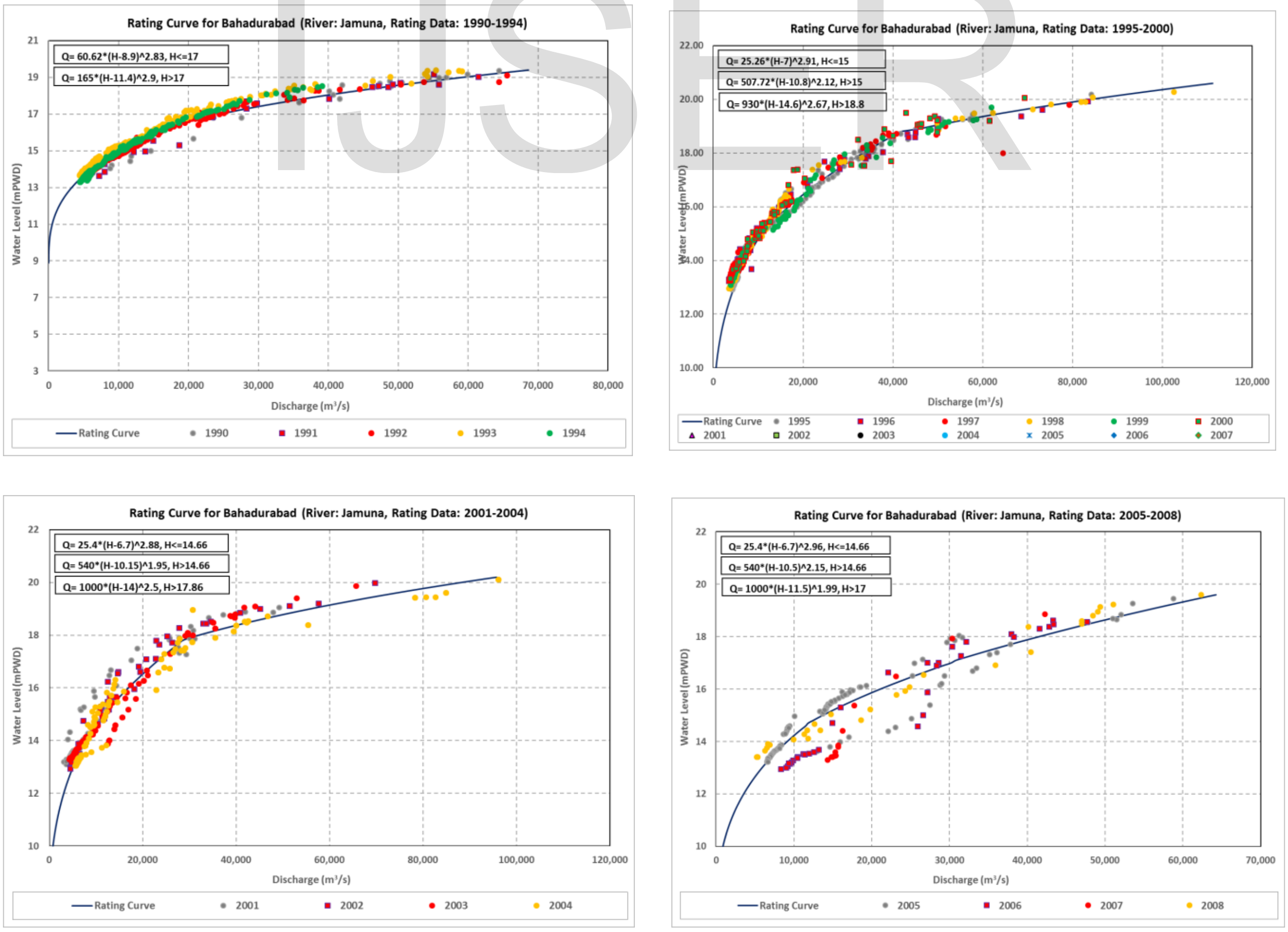

Fig 03. Rating curve of Bahadurabad SW 46.7 (2000-2013)

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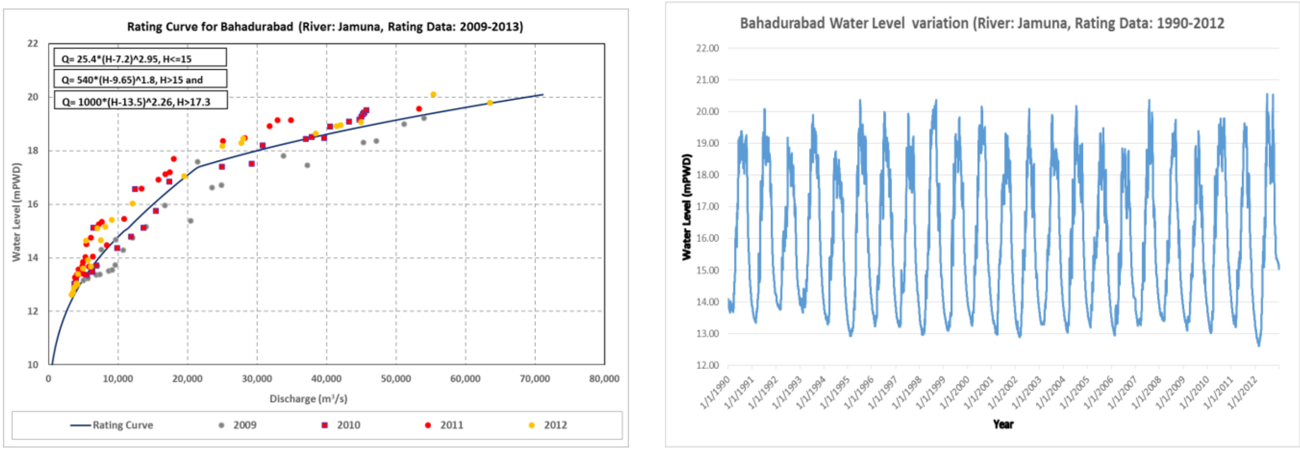

Fig 02. Rating curve of Bahadurabad SW 46.7 (2001-2004)

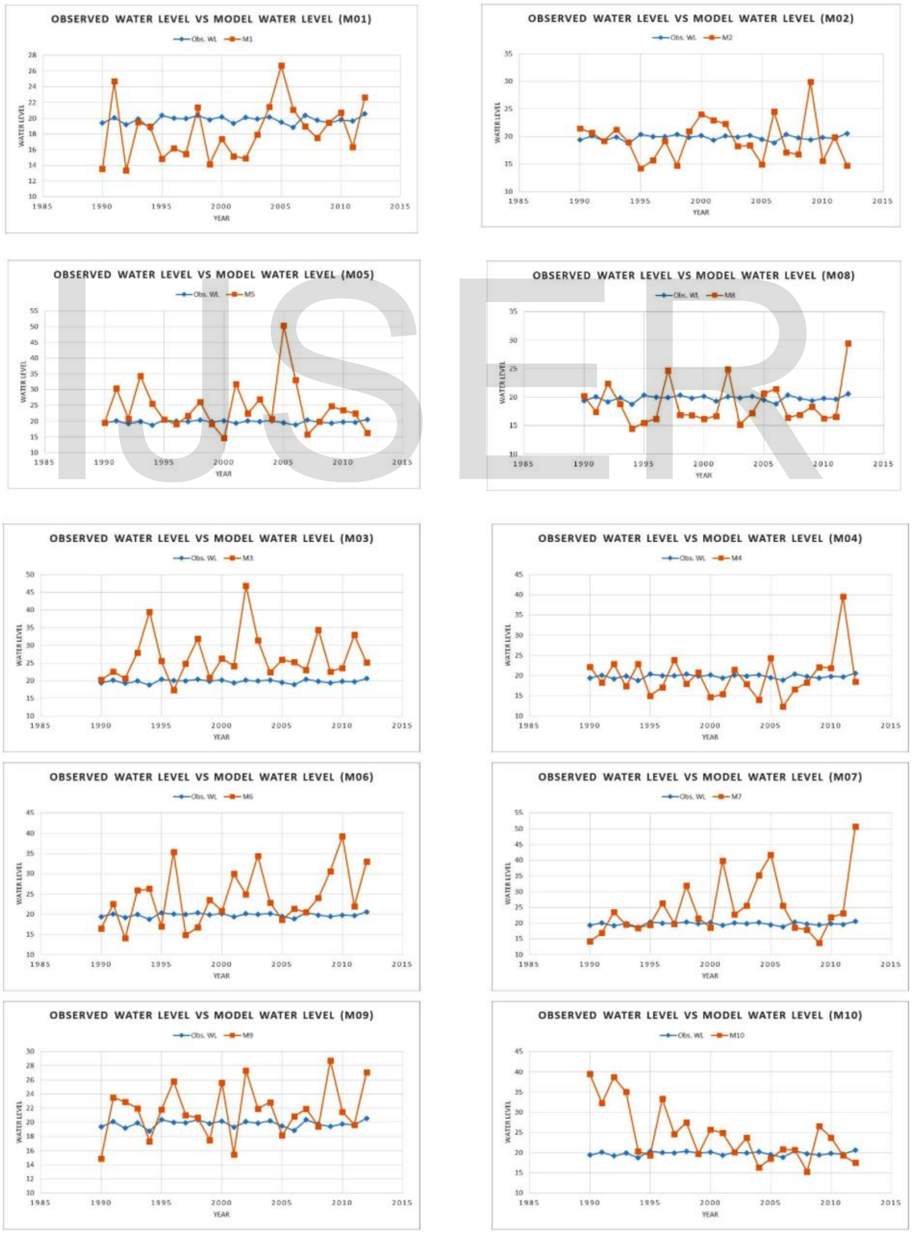

Fig 04. Comparison of observed water level and Model water level of Bahadurabad SW 46.7 (2000-2013)

International Journal of Scientific & Engineering Research, Volume 7, Issue 6, June-2016
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After generating the rating curves in this way, the water level hydrographs have been drawn using appropriate rating curves of Bahadurabad station (SW 46.7). Generated water level hydrographs for different models of SWAT (M01-M10) are shown in Fig.10. According to the simulation water level the SWAT-M04 shown the appropriate variation of water level with the observed water level of that station (Fig 02 & Fig 03).So with this SWAT-M04 model data has been selected to calculate the water level of study area on Turag River (SW302, Mirpur).

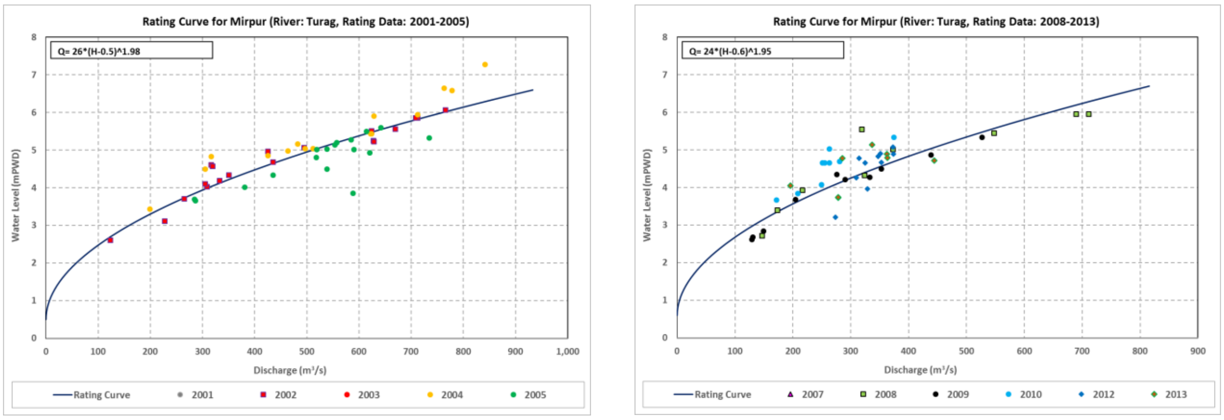

Fig 05. Rating curve of Turag River, Mirpur SW302 (2001-2005)

According to the observed Turag River Discharge data were compared with the SWAT-M04 and Mirpur (SW302) on Fig 12 which will be change to water level of this station with the help of rating curves (Fig 04 and Fig 05) of this station.

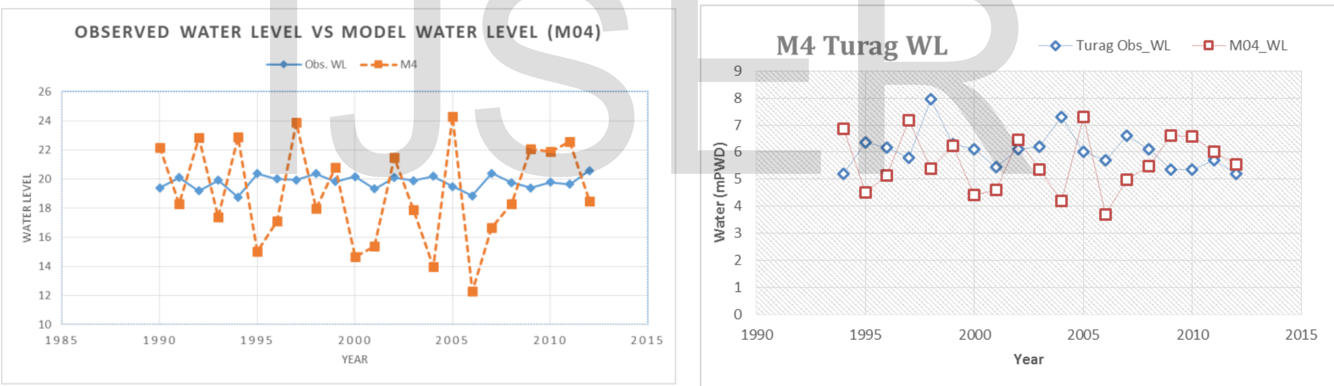

Fig 06. Observed and Model water level of Bahadurabad (SW 46.7) and Mirpur SW302 (1990-2012)

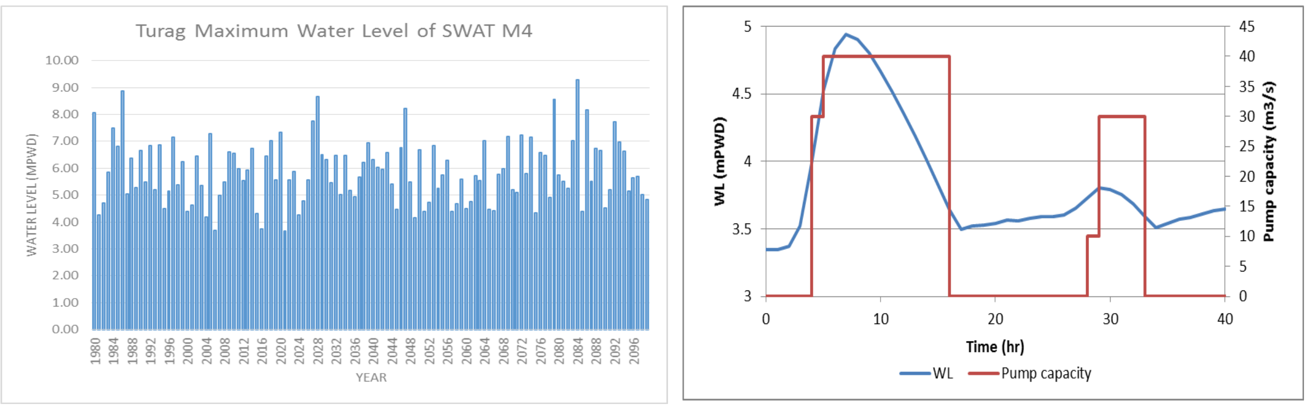

Fig 07. Model water level of 1980-2099 and Observed Pump water level and Discharge of GCB

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The projected water level hydrographs show a general trend of increase in discharge in the Turag River due to climate change for the years 1980 to 2099 (Fig 07). The projected water level hydrographs show that the maximum water level will cross and remain above the danger level for 30 days in Turag in the year 2030, 2048 and 2085. Compared to the flood durations at these locations in 1998, the projected flood durations in 2030, 2048 and 2085 suggest significant worsening of flood situation for the study area GCB SWMM. Corresponding water-level hydrographs for 120 years are shown in Fig 16. The projected hydrographs have been drawn at Turag river (SW 302) incorporating the water level of Observed location of Turag River and Model Data.

Table 5: Changes of water level of Turag River and GCB drainage Model pump water level

River	**Turag (SW 302, Mirpur)**		
HFL 2010 (mPWD)	5.35		
Effect of Brahmaputra (mPWD)	2030	2048	2085
	8.63	8.24	9.02
Effect of GCB (mPWD)	1.05	1.20	1.27
Expected WL (mPWD)	9.68	9.44	10.29
Existing Embankment Height (m) is 9.40			

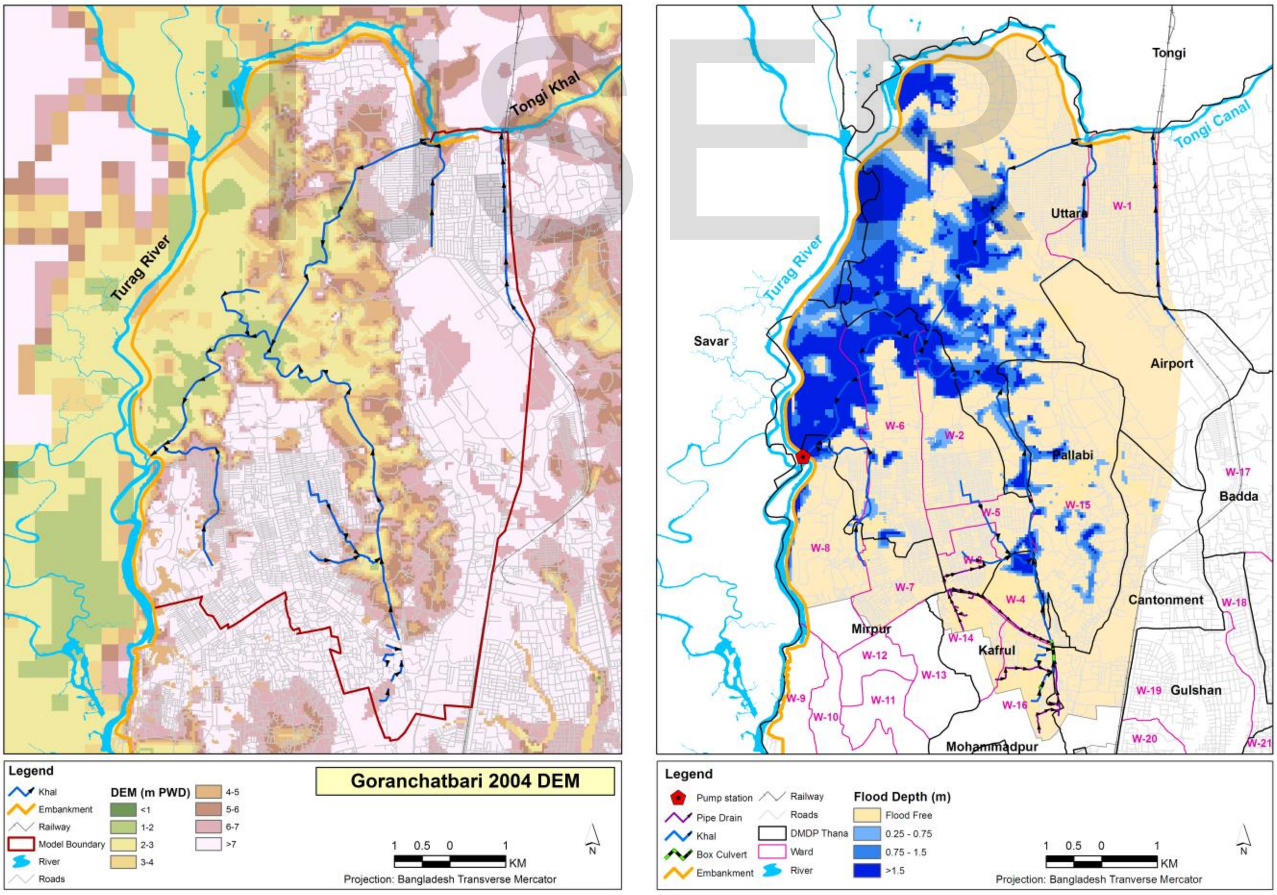

Fig 08. Change of DEM of study area due to water logging due to climate change water level increment of Turag river water level.

The combined effects of increased precipitation and increased discharge and water level in the major rivers will directly affect the study area for drainage, which is surrounded by the Turag River. The increased discharge and water level, particularly for the river Brahmaputra, will affect the discharge and water level in the rivers surrounding Dhaka like Turag. This and the impact of the change in local rainfall around Dhaka have been used to estimate the projected water levels in the rivers surrounding study area. Change of water level also can affect the pumping capacity of GCB (Fig 07).

5. Impact on Climate Change on GCB Model

The increased river discharge and water level of Turag (SW302) will cause flooding, while the expected increase of precipitation will cause water logging in the western part of the Dhaka city. The average existing embankment height in the west part of the city is about 9.4 m. The projected peak water level given in Table 6 shows that in all parts of the city, floodwater will overtop the existing embankment if Climate Change will be considered. In the year 2030 the existing embankment height needs to be raised by 0.28 m (including a free board of 0.6 m). The corresponding value by the year 2048 is 0.04 m and 2085 is 0.89 m according to the effects of Brahmaputra River due to climate change. In other words, to provide adequate protection against flood in 2030, height of the existing embankment will have to be raised by about 0.28 m. Total capacity of the pumps used for draining runoff generated within the city is about 60 cumec. This will not be adequate to pump the increased runoff generated by the increased precipitation. Projected scenario for the flooding zones due to extreme rainfall inside the city with the overtopping of Turag water level for the years 2048 are shown on Fig 18. Which will affect the urban drainage plan for GCB according to SWMM that several portions of this area will be flooded. It is evident that runoff volume exceeds the existing installed pumping capacity both in the ears 2030 and 2048. The existing pumping capacity of Goranchatbari pumping station is 60 cumec, whereas, in the second week of July 2030 and 2048 the runoff volume will be 60.24 cumec and 69.46 cumec respectively. This runoff volume has been calculated based on 7-day average rainfall. Similar calculation was performed based on the 2-day average rainfall, which also gave similar but more critical results - runoff volume for 2030 and 2050 came out to be 105.82 cumec and 122.03 cumec respectively. Thus, the existing pumping capacity is going to fail only in one week during the monsoon based on 7-day average rainfall pattern. Since there would be episodes of intense short duration rains, the installed pumping capacity will be exceeded by internal runoff more frequently.

6. Adaptation and Mitigation Measures

The combined effects of increased precipitation, discharge and water level in the major rivers will directly affect the Dhaka city through external flooding and internal drainage congestion. A number of coping and mitigation measures can be envisioned to deal with this issue. In terms of physical adaptation, it is imperative that the height of the present embankment has to be raised by about 1 meter. At the same time, this consideration has to be included in the design of the embankment for the western part of the city, which is supposed to be built in the near future according to future land-use change. Also additional pumps need to be installed which will increase the costs of pumping. (Fig 09)

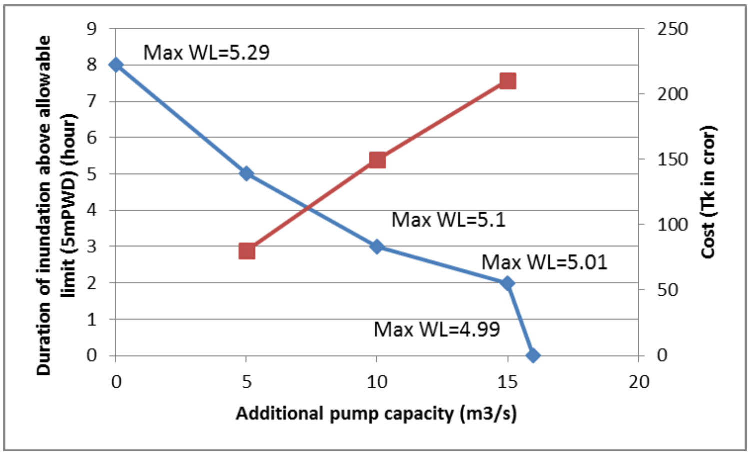

Fig 09. Additional pump capacity will be increased due to climate change of Brahmaputra River.

7. Conclusions

In terms of drainage management, it seems that the present pumping capacity will be able to provide protection for many years with occasional failure to meet the peak demand. This aspect may be dealt with by either having a few emergency pumps stand-by for the most critical week of the monsoon, or by having increased temporary storage inside the city by creating lakes and reservoirs. This second option can be easily pursued for the presently unprotected western part of the city, Goranchatbari by procuring adequate lands for drainage lagoons. In addition, a series of other structural and non-structural and institutional measures will be needed to make physical adaptations more effective. These may include better flood forecasting, enhancing internal drainage system and ensuring prompt inter-agency co-ordination between the agencies involved in flood and drainage management of Goranchatbari area.

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